Designation: C1609/C1609M – 24

Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)[1]

This standard is issued under the fixed designation C1609/C1609M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method evaluates the flexural performance of fiber-reinforced concrete using parameters derived from the load-deflection curve obtained by testing a simply supported beam under third-point loading using a closed-loop, servo-controlled testing system.

1.2 This test method provides for the determination of first-peak and peak loads and the corresponding stresses calculated by inserting them in the formula for modulus of rupture given in Eq 1. It also requires determination of residual loads at specified deflections, the corresponding residual strengths calculated by inserting them in the formula for modulus of rupture given in Eq 1 (see Note 1). It provides for determination of specimen toughness based on the area under the load-deflection curve up to a prescribed deflection (see Note 2) and the corresponding equivalent flexural strength ratio.

NOTE 1—Residual strength is not a true stress but an engineering stress computed using simple engineering bending theory for linear elastic materials and gross (uncracked) section properties.

NOTE 2—Specimen toughness expressed in terms of the area under the load-deflection curve is an indication of the energy absorption capability of the particular test specimen, and its magnitude depends directly on the geometry of the test specimen and the loading configuration.

1.3 This test method utilizes two preferred specimen sizes of 100 mm by 100 mm by 350 mm [4 in. by 4 in. by 14 in.] tested on a 300 mm [12 in.] span, or 150 mm by 150 mm by 500 mm [6 in. by 6 in. by 20 in.] tested on a 450 mm [18 in.] span. A specimen size different from the two preferred specimen sizes is permissible.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C78/C78M Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C125 Terminology Relating to Concrete and Concrete Aggregates

C172/C172M Practice for Sampling Freshly Mixed Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C823/C823M Practice for Examination and Sampling of Hardened Concrete in Constructions

C1140/C1140M Practice for Preparing and Testing Specimens from Shotcrete Test Panels

C1812/C1812M Practice for Design of Journal Bearing Supports to be Used in Fiber Reinforced Concrete Beam Tests

E4 Practices for Force Calibration and Verification of Testing Machines

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C125.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *end-point deflection, n*—the deflection value on the load-deflection curve equal to 1/150 of the span length, or a larger value as specified at the option of the specifier of tests.

3.2.2 *first-peak load, P_1, n*—the load value at the first point on the load-deflection curve where the slope is zero.

3.2.3 *first-peak deflection, δ_1, n*—the net deflection value on the load-deflection curve at first-peak load.

3.2.4 *first-peak strength f_1, n*—the stress value obtained when the first-peak load is inserted in the formula for modulus of rupture given in Eq 1.

3.2.5 *load-deflection curve, n*—the plot of load versus net deflection of a flexural beam specimen loaded to the end-point deflection.

3.2.6 *net deflection, n*—the deflection measured at mid-span of a flexural beam specimen exclusive of any extraneous effects due to seating or twisting of the specimen on its supports or deformation of the support and loading system.

3.2.7 *peak load, P_P, n*—the maximum load on the load-deflection curve.

3.2.8 *peak-load deflection, δ_P, n*—the net deflection value on the load-deflection curve at peak load.

3.2.9 *peak strength, f_P, n*—the stress value obtained when the peak load is inserted in the formula for modulus of rupture given by Eq 1.

3.2.10 *D*—nominal depth of the beam specimen in mm.

NOTE 3—To simplify nomenclature, the nominal beam depth is shown in units of mm for both the SI and inch-pound version of this test method.

3.2.11 *L*—span length or distance between the supports.

3.2.12 *residual load, P^D_{600}, n*—the load value corresponding to a net deflection of L/600 for a beam of nominal depth D.

3.2.13 *residual load, P^D_{150}, n*—the load value corresponding to a net deflection of L/150 for a beam of nominal depth D.

3.2.14 *residual strength, f^D_{600}, n*—the stress value obtained when the residual load P^D_{600} is inserted in the formula for modulus of rupture given in Eq 1.

3.2.15 *residual strength, f^D_{150}, n*—the stress value obtained when the residual load P^D_{150} is inserted in the formula for modulus of rupture given in Eq 1.

3.2.16 *specimen toughness, T^D_{150}, n*—toughness of beam specimen of nominal depth D at a net deflection of L/150.

3.2.17 *equivalent flexural strength, $f^D_{e,\,150}$, n*—the average stress value obtained from the flexural toughness of the beam specimen (absorbed energy calculated from the load-deflection curve), using Eq 3.

3.2.17.1 *Discussion*—ACI 544.4R-18[3] refers to $f^D_{e,\,150}$ as $f_{e,\,3}$.

3.2.18 *equivalent flexural strength ratio, $R^D_{T,\,150}$, n*—the equivalent flexural strength divided by the first-peak strength, expressed as a percentage.

NOTE 4—The equivalent flexural strength ratio is calculated as the ratio of the weighted equivalent load up to a net deflection of L/150 over the first-peak load multiplied by 100. The $R^{150}_{T,\,150}$ value is equivalent to the $R_{e,3}$ value defined in the Technical Report No. 34 of the Concrete Society.[4]

4. Summary of Test Method

4.1 Molded or sawn beam specimens having a square cross-section of fiber-reinforced concrete are tested in flexure using a third-point loading arrangement with a closed-loop, servo-controlled testing system and roller supports under the ends of the beam that are free to rotate on their axes as described in Practice C1812/C1812M. The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E4. Load and net deflection are monitored and recorded to an end-point deflection of at least 1/150 of the span. Data are recorded and plotted by means of an X-Y plotter, or they are recorded digitally and subsequently used to plot a load-deflection curve. Points termed first-peak, peak, and residual loads at specified deflections are identified on the curve, and are used to calculate flexural performance parameters.

5. Significance and Use

5.1 The first-peak strength characterizes the flexural behavior of the fiber-reinforced concrete up to the onset of cracking, while residual strengths at specified deflections characterize the residual capacity after cracking. Specimen toughness is a measure of the energy absorption capacity of the test specimen. The appropriateness of each parameter depends on the nature of the proposed application and the level of acceptable cracking and deflection serviceability. Fiber-reinforced concrete is influenced in different ways by the amount and type of fibers in the concrete. In some cases, fibers may increase the residual load and toughness capacity at specified deflections while producing a first-peak strength equal to or only slightly greater than the flexural strength of the concrete without fibers. In other cases, fibers may significantly increase the first-peak and peak strengths while affecting a relatively small increase in residual load capacity and specimen toughness at specified deflections.

5.2 The first-peak strength, peak strength, and residual strengths determined by this test method reflect the behavior of fiber-reinforced concrete under static flexural loading. The absolute values of energy absorption obtained in this test are of little direct relevance to the performance of fiber-reinforced concrete structures since they depend directly on the size and shape of the specimen and the loading arrangement.

5.3 The results of this test method may be used for comparing the performance of various fiber-reinforced concrete mixtures or in research and development work. They may also be used to monitor concrete quality, to verify compliance with construction specifications, obtain flexural strength data on fiber-reinforced concrete members subject to pure bending, or to evaluate the quality of concrete in service.

[3] ACI 544.4R-18: Guide to Design with Fiber-Reinforced Concrete, American Concrete Institute, Farmington Hills, MI, http://www.concrete.org.

[4] "Concrete Industrial Ground Floors—A Guide to Design and Construction," Technical Report 34, 3rd edition, Concrete Society, Slough, United Kingdom, 2003.